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Circular No. 592

December 1940 · Washington, D. C.

UNITED STATES DEPARTMENT OF AGRICULTURE

Machinery for Growing Corn[1]

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INTRODUCTION

It is the purpose of this circular to report some of the findings and observations from extended studies of the labor, power, and machinery used in growing corn in the central area of the Corn Belt. The results of these studies should be of assistance to the corn grower in selecting the operating methods and machines best suited to his conditions for preparing seedbed, planting and cultivating corn. Corn has the highest money value of any crop grown in the United States and has the largest acreage of the intertilled crops. Some of the observations made pertaining to corn are applicable to other intertilled crops.

The corn grower has need for specialized information in several lines including economics, agronomy, biology, and engineering as related to corn production. Before starting to grow the crop he must decide upon farm management practices to be followed, treatment of the soil, suitable variety or hybrid seed to be used, rate of planting, cultural practices, protection of the crop from diseases and insect damage, and similar matters. Then comes the execution of

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[1] Projects 395, 396, 476, and 543, Iowa Agricultural Experiment Station.

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the program of preparing the seedbed, planting, cultivating, and harvesting which is accomplished by means of labor, power, and machinery. This is the engineering phase of corn growing since engineering, as usually defined, treats in part of labor efficiency, power economy, and the effective use of mechanical equipment.

Although great progress has been made in certain areas in improving labor efficiency, previous to the recent studies little attention had been given to an analytical study of the problems involved. In the United States favorable conditions for growing corn in certain areas and the economic influence of relatively expensive labor have stimulated advances in engineering practices. In many respects, the human aspect is the most important to be considered in connection with the production of any crop. Yields per acre, conservation of fertility, and total production, need to be given proper emphasis but the well-being and effectiveness of the individual laborer should not be minimized.

Perhaps no other crop is produced under such varied conditions and with so wide a range of labor efficiency as corn. Topography is no doubt the most important influence. Although corn can be grown more easily on fertile, level, and well-drained land in fields of relatively large size, corn is grown in some sections on steep hillsides under extremely difficult conditions.

Investigations by several State experiment stations of the labor used in producing corn reveal how wide is the range of labor expenditures. The lowest labor efficiency is recorded for small hillside farms with low yields, where a total of 504 acres of corn produced on 82 farms yielded 1.2 bushels per day of labor [2] or 1 bushel in about 500 minutes. In the same State on rolling land 1 bushel was produced in 56 minutes.[3a] In another State where corn is grown as the principal crop, the average amount of labor used on 678 farms to produce an acre of corn yielding on the average 34 bushels, was 60 hours, or 1 bushel in about 106 minutes.[3]

A study of the records of the members of the Iowa Farm Business Association indicated that farmers with various types of equipment averaged from 6.31 to 14.84 man-hours to grow and harvest 1 acre of corn yielding in 1937 an average of about 60 bushels per acre. On the basis of this yield the labor ranged from 6.31 to 14.84 minutes per bushel.[4]

These recorded examples of labor input will be of interest in connection with the experimental results reported in this circular. Under the favorable conditions of 1939, in one experiment for example, 3.85 man-hours of labor were employed in growing and harvesting a crop yielding 85.8 bushels per acre, or 2.7 minutes per bushel. This record can be duplicated by farmers using similar equipment under favorable conditions.

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[2] NICHOLLS, W. D., BONDURANT, JOHN H., and GALLOWAY, Z. L. FAMILY INCOMES AND LAND UTILIZATION IN KNOX COUNTY. Ky. Agr. Expt. Sta. Bul. 375, pp. [154]–219, illus. 1937.

[3] HERRMANN, L. F., STELZER, R. O., and ARMENTROUT, W. W. LABOR INPUT ON WEST VIRGINIA FARMS. W. Va. Agr. Expt. Sta. Bul. 286, 12 pp., illus. 1937.

[3a] ROUSE, W. L., and BYERS, GEO. B. PRODUCTION REQUIREMENTS FOR CROPS AND LIVESTOCK IN THE BLUEGRASS REGION OF KENTUCKY. Ky. Agr. Exp. Sta. Bull. 383, 96 p. illus., 1938.

[4] GOODSELL, WYLIE D. COST AND UTILIZATION OF POWER AND LABOR ON IOWA FARMS. Iowa Agr. Expt. Sta. Res. Bul. 258, pp. [317]–363, illus. 1939.

In considering the labor requirement it is well to recognize that the labor used in growing corn is not continuous. Not only is the demand for labor intermittent on account of the needs of the crop, but farm work is interfered with by the weather. Finally, labor per bushel is influenced directly by the yield per acre.

Power requirements do not vary as much as labor, indicating that there is not as much a replacement of labor as there is an actual increase in labor effectiveness. In connection with the records of high labor input previously cited for various conditions, the horse work for hillside farms was not given, but in the two other instances it was 56 and 36.4 hours per acre. On the farms of the Iowa Farm Business Association members, it varied from 19.10 to 45.70 horsepower hours per acre. These figures for power are not particularly different from the data recorded in this bulletin. It has been noted in some instances that with larger power units, there is a tendency to do more work in preparing the seedbed and cultivating, thus increasing the power used per acre.

CORN-MACHINERY INVESTIGATIONS

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A study of corn production machinery has been carried on at Ames, Iowa, since 1931 in cooperation between the Bureau of Agricultural Chemistry and Engineering, United States Department of Agriculture and the Agricultural Engineering Section, Iowa Agricultural Experiment Station. The field experiments were located on the Iowa State College Agricultural Engineering Research Farm, a soil map of which is shown in figure 1. The topography of this farm is relatively flat and the natural surface drainage inadequate. A system of tile drainage has been installed but during heavy rains some ponds form in the fields.

The purpose of the investigations was to test the performance of the various machines available for use in corn production. The information obtained included time and draft tests to measure labor and power requirements, observations of the effect upon weed control, and measurement of the effect upon yield of corn.

Conventional machines as purchased from manufacturers were used in these experiments, except where otherwise stated. Experimental machines or attachments were designed and built in some cases when it was desired to do experimental work that could not be performed satisfactorily with conventional machines.

This project did not include any study of the economy of animal as compared to tractor power. The power used in field experiments was furnished by tractors. The kind of work done by a machine, a disk harrow for example, and the amount of energy required to operate it over an acre of land are the same regardless of the source of power; therefore much of the information obtained in this study is applicable to horse-drawn as well as to tractor-drawn machines.

Agronomic experiments conducted for many years at various experiment stations have provided information relative to soil management and cultural practices which produce the best yields of corn on different soils and under different climatic conditions. It is thought that the results of the machinery investigations at Ames, if considered in conjunction with results of agronomic investigations, will help the corn grower to select the best machines and methods for growing corn under various conditions. Two objectives should be kept in mind in applying these results to farm practice: (1) To reduce labor, power, and machinery costs; and (2) to improve weed control and crop yields.

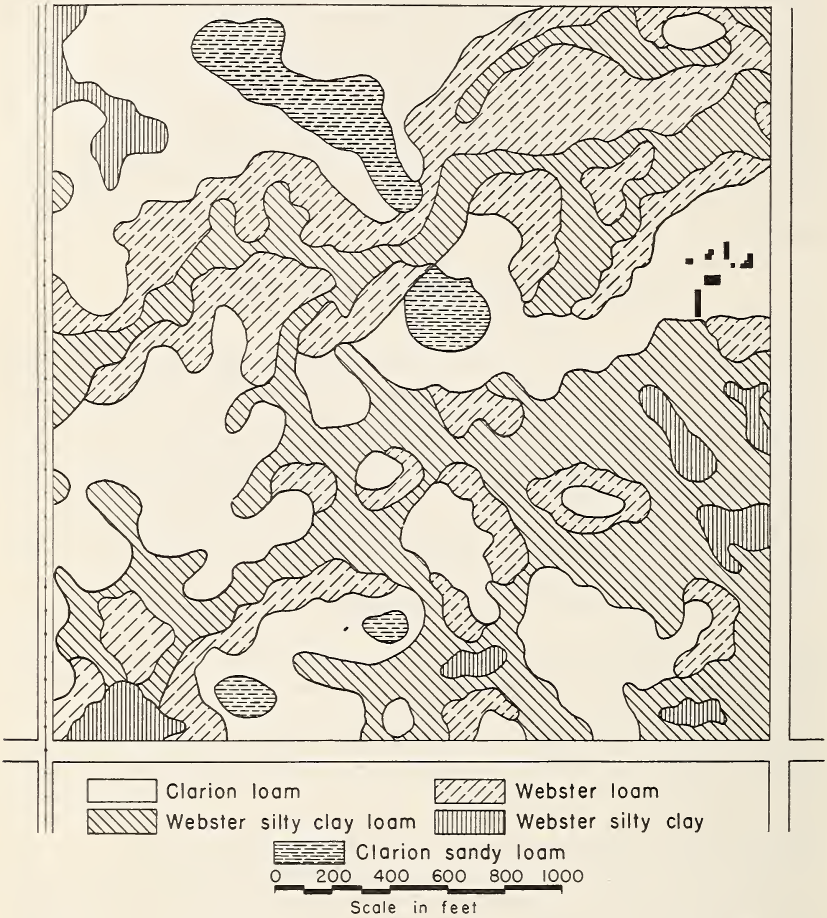

FIGURE 1.—Soil map of 160 acres where the major portion of the field experimental work was done. (Soil Survey, Agricultural Engineering Farm, Iowa State College—mapped by H. R. Meldrum, of the Soils Department, June, 1936).

FIELD OPERATIONS IN CORN CULTURE

In the central part of the Corn Belt, corn is usually surface-planted, that is the seed is deposited just deep enough to be in moist soil and the soil surface is neither ridged nor furrowed. For this method of planting, a typical program of operations in preparing seedbed, planting, and cultivating is shown in table 1, in which horses are used for power in teams about as large as generally considered practicable. Table 1 also shows a revised program using tractor machinery and fewer operations. In the machinery research work at Ames this program has produced good results with considerably less labor.

TABLE 1.—*Labor and power used in field operations in corn culture by surface-planting method with horses and with tractor*

Approximate dates	Machines used	Labor per acre	Power per acre
	USUAL PROGRAM—HORSES FOR POWER[1]		
		Man-hours	*Horsepower-hours*
Mar. 25	Spike-tooth harrow to break stalks, 20-foot, 4 horses	0.25	0.98
Apr. 5	Single disk harrow, 10-foot, 6 horses	.43	2.52
Apr. 10	2-14-inch plow, 6-horses	1.83	11.01
Do	Spike-tooth harrow, 20-foot, 4 horses	.25	.98
Apr. 20	Single-disk harrow, 10-foot, 6 horses	.43	2.52
May 8	do	.43	2.52
May 10	Spike-tooth harrow, 20-foot, 4 horses	.25	.98
Do	Check-row planter, 2-row, 2 horses	.69	1.37
June 3	Cultivator, 2-row, 4 horses	.59	2.33
June 15	do	.59	2.33
July 2	do	.59	2.33
	Total	6.33	29.87
	REVISED PROGRAM—17- TO 25-HORSEPOWER TRACTOR FOR POWER		
Mar. 25	Spike-tooth harrow to break stalks, 30-foot	0.08	0.6
Apr. 5	2-16-inch plow and 42-inch rotary hoe	.88	13.0
May 9	8-foot tandem disk harrow and 10-foot spike-tooth harrow (cut 9-foot)	.34	3.4
May 10	Check-row planter, 4-row	.25	.8
June 3	Cultivator, 2-row	.44	2.6
June 15	do	.44	2.6
July 2	do	.34	2.6
	Total time in field	2.77	25.6
	Estimated labor servicing equipment, etc., 10 percent	.28	
	Total	3.05	25.6

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[1] Compiled from Iowa Agr. Exp. Sta. Bull. 264: Horses, Tractors, and Farm Equipment, by John A. Hopkins, Jr.

Labor and power expenditures recorded in the lower part of table 1 and in other tables in this publication were determined by draft tests of the machines and by detailed time records of the operation of the machines on the Agricultural Engineering Research Farm at Ames, Iowa. The labor recorded for each machine is from one or more time records under normal operating conditions in fields 80 rods long. It covers all time spent in the field including stops and turns.

The time required for miscellaneous work such as greasing machines, servicing the tractor and traveling to and from fields is not included in tables except where shown as a separate item as it is in table 1. In the use of tillage, planting, and cultivating machines with tractor power, under normal conditions miscellaneous labor should not exceed 10 percent of the total.

The size of tractor is designated by the rating given this model of tractor in reports of Nebraska tractor tests (to nearest horsepower).

SEEDBED PREPARATION

The requirements for a good seedbed may be stated as follows:

1. Crop residue or trash to be covered deep enough so that it will not interfere with the operation of planters or cultivators and so it will be kept moist in the soil.
2. The soil to be loose enough for aeration and for easy penetration of tillage machines but with no large air spaces and compact enough to retain moisture around the seed and the plant roots.
3. The surface leveled off so that planter and cultivator will penetrate to uniform depth. A cloddy surface is usually preferred to a very finely pulverized and compacted surface such as desired for grass seeding.
4. The soil free from growing weeds at the time of planting the corn.

Seedbed preparation may be considered in three steps: (1) Disposal of the residue of the previous crop; (2) primary preparation (usually plowing); and (3) secondary preparation or work on the soil after plowing and up to the time of planting.

Disposal of Crop Residues

Usually it is not necessary to dispose of crop residue or other trash on clover or oats stubble prior to plowing. If harvesting is done with a combine, the straw should be scattered as uniformly as possible. If straw is left in windrows or bunches, it may be difficult or impossible to do a good job of plowing especially if the straw is wet at the time of plowing. In preparing ground where the previous crop was corn, some farmers rake and burn the cornstalks but the more usual practice is to use a disk harrow to cut up the stalks and partially mix them with the surface soil before plowing.

In the experiments little if any work on cornstalks was necessary before plowing. Where the corn had been machine-harvested and the plowing was done crossways of the direction of harvesting, plows covered stalks satisfactorily without any previous preparation. There was no apparent improvement in quality of plowing when the stalks were cut up with a disk harrow or a stalk cutter before plowing. When plowing in the same direction as harvesting, it was found advantageous to harrow the stalks crossways or diagonally previous to plowing in order to distribute the stalks and prevent all of the stalks on a row from being plowed into a single furrow. When cultivators equipped with sweeps and disk hillers rather than pointed shovels were used, there was usually no difficulty in cultivating as a result of plowing under whole cornstalks. The labor and power requirements for work on cornstalks previous to plowing were found to be as recorded in table 2.

Table 2.—*Labor and power used in disposing of cornstalks before plowing*

Method	Labor per acre	Power per acre
	Man-hours	*Tractor-hours*
Harrow, rake, and burn	0.47	0.38
Cut with disk harrow, 14-foot	.23	.22
Cut with stalk cutter, 2-row	.30	.29

Primary Preparation

Plowing as the primary operation in preparing a seedbed for corn is usually considered necessary for the purpose of covering vegetation and trash if not for other reasons. The fact that plowing is the most expensive single field operation in growing corn, as shown in tables 1 and 9, suggests the possibility of economizing by substituting a cheaper operation for plowing. Under some conditions plowing may not be necessary or desirable. On well-drained prairie soils where the previous crop was soybeans, farmers have sometimes obtained good results by disk harrowing without plowing to prepare a seedbed for corn. Duley and Kelley[5] in recent investigations in eastern Nebraska found that more rainwater entered the soil when trash was left on the surface than when it was plowed under. Satisfactory methods and machinery for corn culture where trash is left on the surface have not yet been developed.

The following machines were compared under different conditions for primary preparation of seedbed: 14-inch and 16-inch plows, basin lister, deep-tillage cultivator or "chisel," cover-crop tandem disk (22-inch blades spaced 9 inches), and tandem-disk harrow. The labor and power used in preparing seedbed by eight different methods in the 1939 experiments are recorded in table 3. These data show substantial savings in labor and power by substituting cheaper operations for plowing but in some cases, the saving was partially or wholly offset by additional secondary operations necessary to kill clover or weeds.

Yields obtained in replicated plot experiments showed no significant difference resulting from method of primary preparation of seedbed in 1939 when the weather was very dry during April and May. In 1937, when April and May rainfall was about normal, and again in 1938, when there was a considerable excess of rainfall in April and May, plowing produced significant yield increases over the cheaper methods of preparation.

Where there was first-year sweetclover, spring plowing after about April 25 killed the clover but none of the other machines did.

Cornstalks and other trash on the surface of soil prepared by machines other than the plow caused some interference with the operation of machines for secondary preparation, planting, and cultivating.

Table 3.—*Labor and power used by various machines in primary preparation of seedbed for surface-planted corn*

Method No.	Date 1939	Machine used	Labor per acre	Power per acre
		FIELD E-1: PREVIOUS CROPS, OATS-SWEET CLOVER	*Man-hours*	*Horsepower hours*
1	May 2	2-16-inch plow, 7 inches deep and rotary hoe	1.15	18.0
	May 12	8-foot tandem-disk harrow and 10-foot spike-tooth harrow	.34	3.4
	May 26	do	.34	3.4
		Total	1.83	24.8
2	May 2	2-16-inch plow, 4 inches deep and rotary hoe	.88	10.5
	May 12	8-foot tandem-disk harrow and 10-foot spike-tooth harrow	.34	3.4
	May 26	do	.34	3.4
		Total	1.56	17.3

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[5] Duley, F. L., and Kelly, L. L. EFFECT OF SOIL TYPE, SLOPE, AND SURFACE CONDITIONS ON INTAKE OF WATER. Nebr. Agr. Expt. Sta. Res. Bul. 112, 16 pp., illus. 1939.

Table 3.—*Labor and power used by various machines in primary preparation of seedbed for surface-planted corn*—Continued

Method No.	Date 1939	Machine used	Labor per acre	Power per acre
		FIELD E-1: PREVIOUS CROPS, OATS-SWEET CLOVER—Continued	*Man-hours*	*Horsepower hours*
3	May 2	6-foot tandem cover crop disk	0.51	6.0
	May 9	8-foot tandem-disk harrow	.26	2.6
	May 12	8-foot tandem-disk harrow and 10-foot spike-tooth harrow	.34	3.4
	May 20	8-foot tandem-disk harrow	.26	2.6
	May 26	8-foot tandem-disk harrow and 10-foot spike-tooth harrow	.34	3.4
		Total	1.71	18.0
		FIELD F: PREVIOUS CROP, CORN		
4	Apr. 21	2-16-inch plow, 8 inches deep and rotary hoe	1.25	17.0
	May 8	8-foot tandem-disk harrow	.26	2.6
	May 17	8-foot tandem-disk harrow and 10 foot spike-tooth harrow	.34	3.4
		Total	1.85	23.0
5	Apr. 21	2-16-inch plow, 6 inches deep and rotary hoe	.88	13.0
	May 8	8-foot tandem-disk harrow	.26	2.6
	May 17	8-foot tandem-disk harrow and 10-foot spike-tooth harrow	.34	3.4
		Total	1.48	19.0
6	Apr. 22	2-16-inch plow, 4 inches deep and rotary hoe	.88	8.9
	May 8	8-foot tandem-disk harrow	.26	2.6
	May 17	8-foot tandem-disk harrow and 10-foot spike-tooth harrow	.34	3.4
		Total	1.48	14.9
7	Apr. 11	2-row basin lister	.65	4.2
	May 8	8-foot tandem-disk harrow	.26	2.6
	May 17	8-foot tandem-disk harrow and 10-foot spike-tooth harrow	.34	3.4
		Total	1.25	10.2
8	Apr. 22	8-foot tandem-disk harrow	.26	2.6
	May 8	do	.26	2.6
	May 17	8-foot tandem-disk harrow and 10-foot spike-tooth harrow	.34	3.4
		Total	.86	8.6

Weed growth on plowed soil was less vigorous than where lighter primary preparation was given.

The general conclusion from these experiments is that no machine except the plow has been uniformly satisfactory for primary preparation of seedbed. Other results and observations on plowing were as follows: The 16-inch plow was preferable to the 14-inch plow for turning under a heavy growth of cornstalks or other trash. The 16-inch plow did a better job of covering the trash and operated without clogging difficulties under some conditions where the 14-inch plow gave a good deal of trouble because of clogging.

Better coverage of trash was obtained when plowing 5 to 6 inches deep than when plowing either deeper or shallower. Plow jointers of the moldboard type as supplied by manufacturers improved trash coverage provided the jointers scoured. The independently mounted jointer was preferable to the jointer attached to the colter fork. Three types of experimental disk jointers were tried and did good work in sticky or loose soil where the moldboard jointers would not scour.

Power or energy input per acre in plowing was found to be about in proportion to depth; for example, plowing 8 inches deep takes about 60 percent more power than plowing 5 inches deep. Labor requirement is also about in proportion to depth if the same tractor is used and the size of plow or speed of travel is increased in proportion for the shallower plowing. This indicates that there may be a substantial wastage of labor and power by plowing deeper than necessary.

SECONDARY PREPARATION

Plowing leaves the surface of the soil more or less cloddy and uneven and the plowed soil is left in too loose a condition for a good seedbed. A cloddy rough surface from fall plowing is advantageous during the winter as it tends to increase absorption of water from rain and snow and reduces the chances of wind erosion; therefore secondary preparation is usually not started until spring.

For spring plowing, secondary preparation may well begin with the use of a rotary hoe or a spike-tooth harrow at the time of plowing or soon thereafter while the surface clods are moist enough to break up easily. These machines also pack the soil to some extent and thus reduce the loss of moisture from the plowed soil in dry weather.

The use of a section of rotary hoe attached to the plow as shown in figure 2 proved to be best for spring plowing. By attaching the pull chain off center on the rotary hoe frame and hitching directly to the plow frame, the rotary hoe wheels were given enough lead to guide them onto the plowed ground without the use of a special bracket extending from the side of the plow as is required when using a section of spike-tooth harrow. The rotary hoe is pulled backward since in this direction of travel it has little tendency to pick up trash when turning around on headlands.

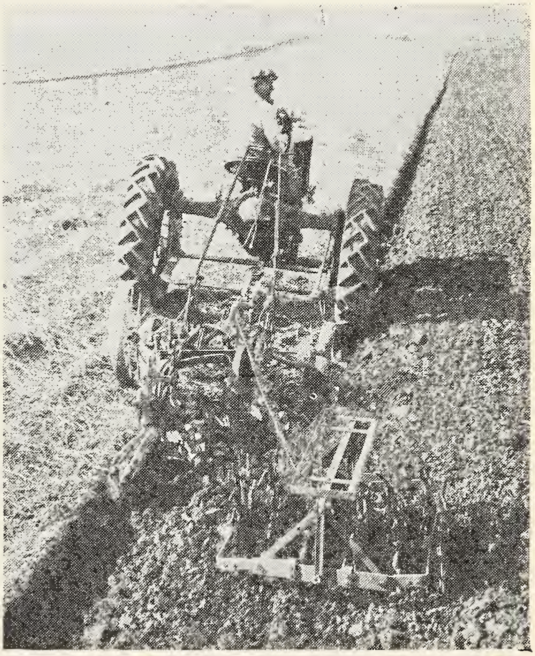

FIGURE 2.—Plowing soybean stubble. Threshing had been done by a combine. It was found advantageous to use a section of rotary hoe attached to the plow for spring plowing. The pull chain was attached off center on the hoe frame, eliminating the need for a hitch bracket on the plow. The hoe was pulled backward so that it would not pick up trash when turning on headlands.

In 1937, 1938, and 1939 replicated plot experiments were carried on in which comparisons were made of different amounts of work as well as different machines for secondary preparation of seedbed. The results are recorded in table 4. Plots in this experiment were all plowed, planted, and cultivated alike, the only difference in treatment being in secondary preparation of seedbed.

The tandem-disk harrow and spike-tooth harrow combination (figure 3) was very effective in destroying weeds, in filling tractor wheel tracks, and in leveling off irregularities in the soil surface at one operation. A comparison of methods 6, 7, and 8, in table 4, shows that a single tillage with tandem-disk harrow and spike-tooth harrow just before planting (method 6) was usually adequate preparation as indicated by yields. The only case in which a significant yield increase was obtained by additional tillage was in 1937 on a fall-plowed field in which sweet clover had not been killed by plowing. In this case the single tillage did not kill all of the sweet clover, which accounts for the reduction in yield.

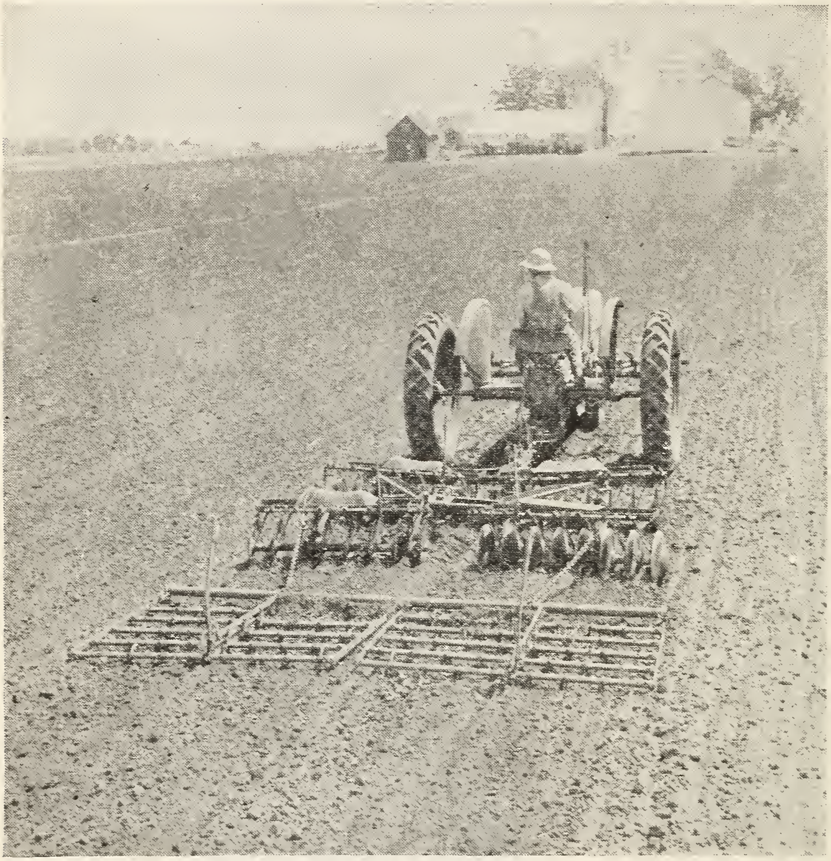

FIGURE 3.—The tandem-disk harrow and spike-tooth harrow combination was found very effective in destroying weeds, filling tractor wheel tracks, and leveling off irregularities in the soil surface at one operation. Under ordinary conditions, one tillage of plowed ground with this combination just before planting was sufficient preparation.

Table 4.—*Labor and power used by various machines in secondary preparation of seedbed and yields, 1937–39*

Method	Date (1939)	Machines used	Labor	Power	1939		1938		1937	
					Yield per acre[1]	Yield per acre[2]	Yield per acre[3]	Yield per acre[4]	Yield per acre[5]	Yield per acre[6]
			Man-hours per acre	*Horse-power-hours per acre*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
1	May 12	2-row sweep cultivator and 2-row check planter (fig. 5)	0.50	3.4	60.7					
2	Apr. 26	2-row disk cultivator (to bed rows)	.34	2.6						
	May 12	2-row sweep cultivator and 2-row check planter	.50	3.4						
		Total	.84	6.0	67.4	86.6				
3	Apr. 27	11½ foot field cultivator (8-inch sweeps) (fig. 4)	.27	2.6						
	May 12	2-row sweep cultivator and 2-row check planter	.50	3.4						
		Total	.77	6.0	66.4	87.6				
4	May 11	14-foot single-disk harrow	.22	2.0						
		30-foot spike-tooth harrow	.08	.8						
		4-row check planter	.25	.8						
		Total	.55	3.6	63.3	85.4				
5	Apr. 26	14-foot single-disk harrow	.22	2.0						
	May 11	14-foot single-disk harrow	.22	2.0						
		30-foot spike-tooth harrow	.08	.8						
		4-row check planter	.25	.8						
		Total	.77	5.6	65.5	87.6				
6	May 11	8-foot tandem-disk harrow and 10-foot spike-tooth harrow (fig. 3)	.34	3.4						
	May 12	4-row check planter	.25	.8						
		Total	.59	4.2	68.2	85.8	81.6	76.0	69.6	73.4
7	Apr. 26	8-foot tandem-disk harrow	.26	2.6						
	May 11	8-foot tandem-disk harrow and 10-foot spike-tooth harrow	.34	3.4						
	May 12	4-row check planter	.25	.8						
		Total	.85	6.8	68.1	88.7	81.8	78.8		
8	Apr. 26	8-foot tandem-disk harrow	.26	2.6						
	May 3	do	.26	2.6						
	May 11	8-foot tandem-disk harrow and 10-foot spike-tooth harrow	.34	3.4						
	May 12	4-row check planter	.25	.8						
		Total	1.11	9.4	67.8	86.3	81.4	76.6	74.4	72.9

[1] Previous crop corn. Plowed and rotary-hoed (fig. 2) Apr. 3–10. Yield differences were highly significant.
[2] Previous crop second-year sweet clover. Plowed in August. Yield differences were not significant.
[3] Previous crop corn. Plowed in November. Yield differences were not significant.
[4] Previous crop oats-sweetclover. Plowed in April. Yield differences were not significant.
[5] Previous crop oats-sweetclover. Plowed in November. Yield differences were significant.
[6] Previous crop oats-sweetclover. Plowed in April. Yield differences were not significant.

The single-disk harrow is a satisfactory machine for secondary preparation of seedbed when horses or a skeleton-wheel tractor is used for power. When the soil was high in moisture, tractors having solid rim wheels or rubber tires left wheel tracks in plowed ground that the single-disk harrow would not fill. Then when the seedbed was finished, the surface was somewhat uneven so that planters and cultivators did not penetrate to uniform depth.

Results recorded in table 4 show that two tillages with the single-disk harrow (method 5) required somewhat higher labor and power expenditures and produced results about equivalent to those obtained by a single tillage with tandem-disk harrow (method 6).

The field cultivator (fig. 4) equipped with 8-inch sweeps was compared with a single-disk harrow in replicated plot experiments in 1934 to 1936 in addition to the experiments recorded in table 4. These two machines produced no significant difference in weed control, stand, or yield. Results recorded in table 4 indicate that a single tillage with a sweep cultivator (method 1) or with a disk harrow (method 4) was inadequate preparation of spring-plowed ground.

The disk harrow acted to improve coverage of trash, press clods down, and pulverize the surface soil; while the cultivator raised clods and some trash to the surface, allowing fine soil to sift down below. Clods and trash on the surface gave the cultivated plots a somewhat untidy appearance, but as stated above this had no unfavorable effect upon growth of the crop.

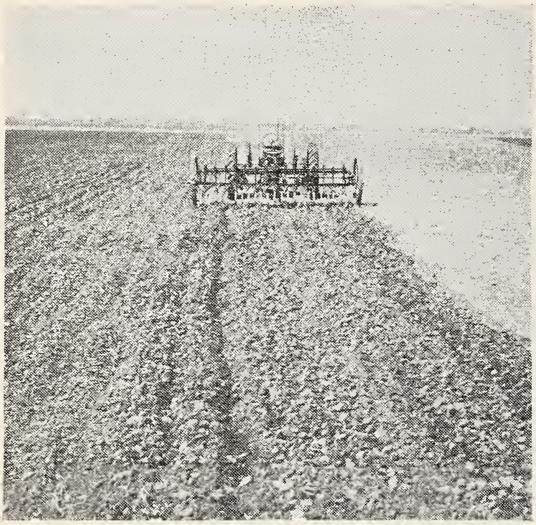

FIGURE 4.—Preparation of seedbed with a field cultivator equipped with 8-inch sweeps gave similar results in weed control, stand, and yield to those obtained by use of a single-disk harrow. One tillage with either of these machines was inadequate preparation of spring-plowed land.

The field cultivator is more effective than the disk harrow in controlling quackgrass and some other perennial weeds. These weeds were not present in the experimental fields at Ames. The cultivator may be equipped with either narrow pointed shovels or sweeps, the narrow shovels being preferred for controlling quackgrass and the sweeps for general use.

Observation of the work done by different machines for lighter operations or final preparation of the seedbed indicated that the lever spike-tooth harrow was generally the best machine for this purpose. After the soil had been tilled with a disk harrow or a cultivator, the spike-tooth harrow was effective in further pulverizing and packing the surface soil as much as desired and in taking down high points and filling small depressions. A roller or cultipacker had little leveling action. It produced a finer pulverized and more compact surface than the harrow but this is not known to be of any advantage for corn. The rotary hoe had little leveling action but was considered preferable to a spike-tooth harrow section for use attached to a plow as shown in figure 2.

The combination of cultivator and planter shown in figure 5 was used in methods 1, 2, and 3, table 4.

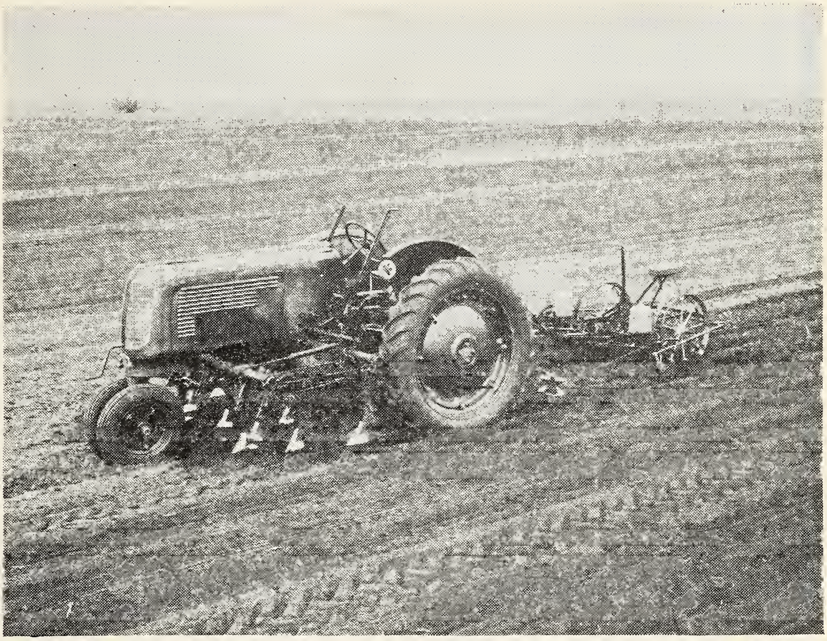

Figure 5.—Cultivator and planter. Final preparation of seedbed and planting in one operation.

WEED CONTROL BY SEEDBED PREPARATION

The theory has been advanced that weeds can be destroyed more effectively or at lower cost by extra work in seedbed preparation than by cultivation of the growing corn. The idea is that if two or more crops of weed seeds can be germinated and killed during the seedbed preparation processes, the soil will then be relatively free from weed seeds and thus cultivation of the growing crop will be made easier.

This theory is applicable to some conditions but it is not well supported by the results recorded in table 4. With planting dates between May 10 and 15 a single thorough tillage at time of planting (method 6) produced yields not significantly different, with one exception, from the yields obtained by methods 7 and 8, which involved additional tillage operations. Weed seedlings did not appear in plowed ground until about May 1 and these were destroyed by one tillage operation at the time of planting. If planting is delayed 1 to 2 weeks, more weeds can, of course, be destroyed in seedbed preparation. From the standpoint of operating costs, it is obvious that additional operations in preparing seedbed will make some small increase in the cost of growing the crop unless corresponding reductions are made in cultivating operations. Additional costs are fully justified if needed to effect good control of weeds.

PLANTING

Check and Drill Planting

Yields of hill planting in checkrows and drill planting were compared in seven different experiments of replicated plot design in 1937–39. The average yield of check planting was 69.9 and of drill planting 71.1 bushels per acre. The yield differences were not significant in any of these experiments.

In addition to the plot experiments, larger areas were planted by each of these methods each year, 1932–38, for purposes of studying labor and power requirements in planting and for testing cultivator equipment.

Results of a time study of checkrow and drill planting made with a four-row tractor-planter in a field having rows one-quarter of a mile long are recorded in table 5. The planter had power lift to raise the planting units and markers. For drill planting, the markers were arranged to also drop automatically so that no stop was necessary when turning around. It was found that the speed limit for good checkrowing was about 3¾ miles per hour. For drill planting under good conditions no objection was found to speeds up to 5 miles per hour.

Table 5.—*Time studies of planter operation*

Item	Check planting	Drill planting
Average speed of travel ______ miles per hour	3.8	4.8
Average time to turn around and change check wire ______ minutes	1.55	______
Average time to turn around ______ do	______	0.17
Rate of work ______ acres per hour	4.5	7.5

Surface and Furrow Planting

Surface planting was compared with furrow planting (using 11-inch disk furrow openers attached to the planter runners) in replicated plot experiments for 3 years, 1934–36. There were no significant differences in yield any year of the 3.

In 1934, a dry year, better stands were obtained by furrow planting but the yield was the same as with surface planting. The possibility of heavy rains after planting and before the plants have grown well above the ground surface adds an element of risk to furrow planting. Even on relatively flat land, some water is likely to flow in the furrows, which may wash out seeds or small plants in some places and cover them too deep with soil in others. Under ordinary conditions at Ames, surface planting was preferable to furrow planting.

Row and Hill Spacing

Rows 42 inches apart and hills 42 inches apart in the row is standard for the central Corn Belt. Some farmers use 40-inch spacing and there is some interest in the possibilities of narrower spacings.

In the machinery experiments, corn was planted and cultivated in row spacings of 21, 30, and 42 inches. Experimental tractor planters and cultivators were used for the 21-inch and 30-inch spacings, the 21-inch machines being six-row and the 30-inch machines four-row. For the 42-inch spacing a regular four-row tractor planter and a two-row tractor cultivator were used.

There was no difficulty in checkrow planting in the narrow spacings except that the speed of travel for 30- by 30-inch spacing had to be reduced a little and for 21- by 21-inch spacing it had to be reduced to not much over half the speed permissible in 42- by 42-inch checkrowing. Cross cultivation of the 30- by 30-inch spacing was not difficult but it was not practicable to cross cultivate the 21- by 21-inch spacing. Corn in the narrow spacings could be "laid by" earlier as it shaded the ground at a somewhat earlier stage of growth.

Labor input was found to depend largely upon the width of machines used rather than upon row spacings. Six-row 21-inch and four-row 30-inch planters and cultivators were practicable sizes on the level to moderately sloping land used in these experiments.

CULTIVATION OF SURFACE-PLANTED CORN

Purposes

Experiments carried on by agronomists for many years at various locations have shown that usually the chief purpose of cultivating corn is to kill weeds. Richey[6] says: "The results of all the experiments considered as a whole indicate that cultivating as often and as deep as necessary to control weeds, and no more, is the desirable practice."

The following facts also should be considered in deciding upon machinery and methods of cultivation. Under some soil and weather conditions, cultivation is necessary when the corn plants are small to prevent injury by sandblowing. Cultivator furrows and ridges tend to increase the intake of water into the soil if the rows are on contours. On the other hand, cultivation causes some loss of moisture by bringing moist soil up to the surface and leaving the surface loose so that it will dry out.

Machines for Early Cultivation

Machines for early cultivation, that is from the time the corn plants emerged until they had grown 8 to 10 leaves, were compared in replicated plot experiments from 1934 to 1939. The machines used and the yields obtained are recorded in table 6. After the cultivations listed, all plots were given two cultivations with equipment effective in destroying weeds.

The most outstanding, and perhaps surprising, result shown by these experiments is the good yields obtained on plots not cultivated until the plants had grown 8 to 10 leaves and stood about 10 inches high. Only in 1935 were yields reduced significantly by omitting early cultivation. That year the June rainfall was 10.50 inches while the normal amount is 4.37 inches. The soil was heavily crusted by intense rainfall the first 2 days of June. Cultivation of all except check plots was performed between June 5 and 14. Rains beginning on June 17 prevented cultivation until July 8, when the check plots received their first cultivation. The results for the 6 years as recorded in table 6 show that corn yields were not materially reduced by weed competition until the corn stood about 10 inches high, provided weeds could be destroyed at that time; but the results recorded in 1935 show that, to be safe from wet weather, early cultivation is advisable. It is suggested, however, that early cultivation with sweep cultivator may well be delayed until the corn plants have grown large enough to permit thorough coverage of weeds in the corn row.

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[6] RICHEY, FREDERICK D. CORN CULTURE. U. S. Dept. Agr. Farmers' Bul. 1714, 26 pp., illus. 1933.

TABLE 6.—*Yields obtained by use of different machines for early cultivation of corn*

Machines used	Average yields per acre					
	1934	1935	1936	1937	1938	1939
	Bushels	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*
Spring-tooth weeder twice	21.0	42.1	32.6	70.6	68.1	65.7
Spring-tooth weeder once	----------	----------	----------	----------	----------	67.3
Rotary hoe twice	21.7	38.4	33.0	70.2	67.8	----------
Spike-tooth harrow twice	22.5	37.8	33.3	67.0	67.2	----------
Sweep cultivator once	21.2	46.2	32.9	70.0	69.3	70.8
Check. No early cultivation	23.7	34.7	32.8	68.7	68.2	71.3

The spike-tooth harrow, spring-tooth weeder (fig. 6) and rotary hoe (fig. 7), work the surface soil enough to kill weed seedlings but not enough to seriously injure corn plants. Success depends upon relative resistance of corn plants and weeds; that is, the corn plants should be well established while the weeds are young. The spike-tooth harrow

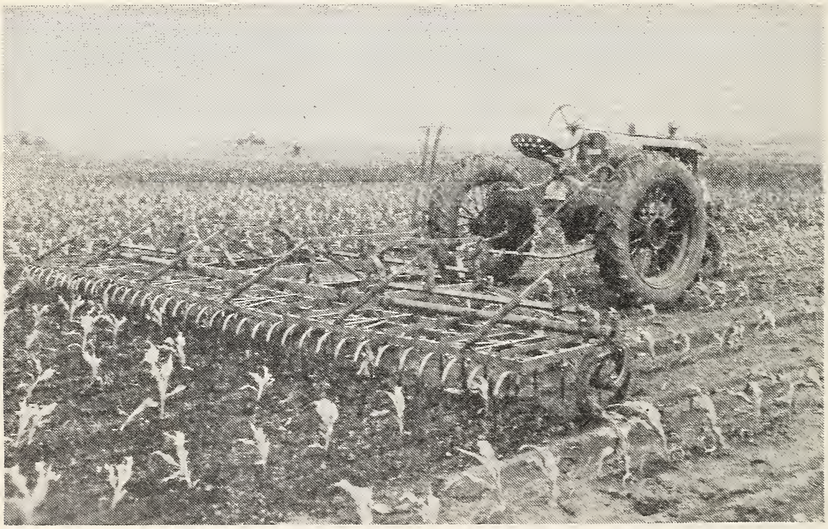

FIGURE 6.—Early cultivation of corn was done quickly and with low expenditure of labor and power with a spring-tooth weeder. It was effective in destroying small weed seedlings when the soil has been lightly crusted by moderate rainfall.

spring-tooth weeder, and rotary hoe do not kill deep-rooted weeds such as cocklebur, which may be as firmly established and as tough as the corn plants. In the experiments listed in table 6, these machines were used the first time when the corn plants had grown about four leaves and had started the first set of crown roots. When there had been moderate rainfall forming a light soil crust, these machines were effective in destroying weeds, but when there was a heavy crust resulting from intense rainfall, as in 1935, only part of the weeds were killed. In 1939 the surface soil remained loose and dry. That year the use of the weeder was found to be ineffective in controlling weeds and it caused material injury to the corn as shown by yields recorded in table 6 and also by stand count at harvest which showed an average of 8,706 plants per acre on the plots cultivated twice with weeder and 10,328 plants per acre on check plots.

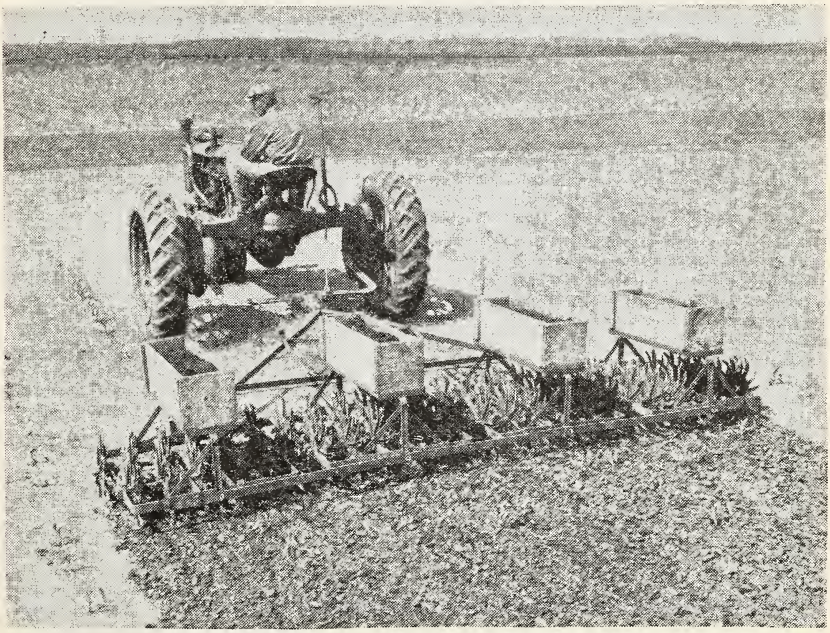

Figure 7.—The rotary hoe performs cultivation similar to that done by the spring-tooth weeder shown in figure 6.

The spike-tooth harrow gave some trouble because of its tendency to gather trash. It caused more injury to corn plants than other machines, but the results recorded in table 6 show that yields obtained by the use of the spike-tooth harrow were not materially lower than those obtained by the use of the rotary hoe except in 1937. The weeder is preferred because its cost is lower, it is lighter in weight, and more convenient to use. It was observed that the weeder could be used until the corn stood about 12 to 15 inches high without any serious injury of corn plants. The rotary hoe could be used until the corn was about 10 to 12 inches high, but the spike-tooth harrow could not be used after the corn was about 8 inches high.

When intense rainfall formed a heavy soil crust and brought fine sand to the surface, any one of these three machines would scratch or dig the surface enough to prevent sand blowing even if it did not break up the crust enough to destroy weeds.

CULTIVATOR EQUIPMENT

In designing, selecting, or adjusting cultivator shovels, sweeps, or disks to suit various conditions, one of the important requirements is to destroy weeds in the corn row where the soil cannot be thoroughly tilled. The weeds in the row should be scratched out or thoroughly covered if possible at each cultivation without covering the corn or unnecessarily ridging the rows.

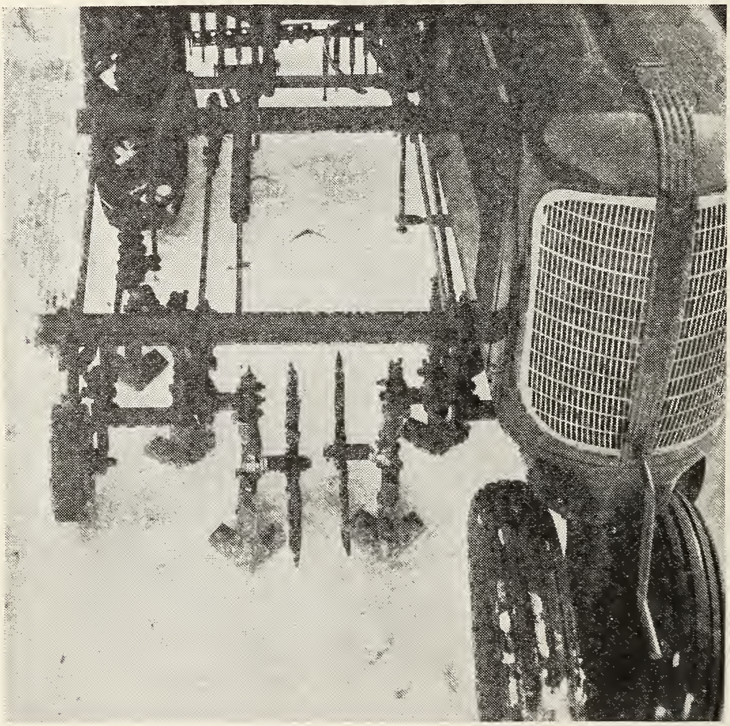

FIGURE 8.—Rotary hoe shields were preferred to solid shields because they regulated more uniformly the amount of fine soil moved into the corn row and they gave less trouble from clogging with trash or damp soil.

Cultivators have usually been equipped with four or six shovels per row. Straight or twisted shovels 4 to 6 inches wide were commonly used a few years ago but more recently spearhead shovels 5 to 6 inches wide have generally been preferred. Sweeps 8 to 12 inches wide have come into use to a considerable extent on tractor cultivators. Disk hillers, which may be used to replace shovels or sweeps when desired, are now offered for sale by tractor-cultivator manufacturers but have not yet come into very extensive use.

In the experiments recorded in table 6, the cultivator used for early cultivation was equipped with six sweeps per row and rotary hoe shields as illustrated in figures 8 and 9. The rotary hoe wheels were preferable to solid shields as they regulated more uniformly the amount of soil moved into the row by the sweeps, they gave less trouble from clogging with trash, clods, or damp soil, and they also tilled the soil near the corn plants. This equipment was generally used when the corn plants were at about the four-leaf stage of growth but sometimes when they were smaller.

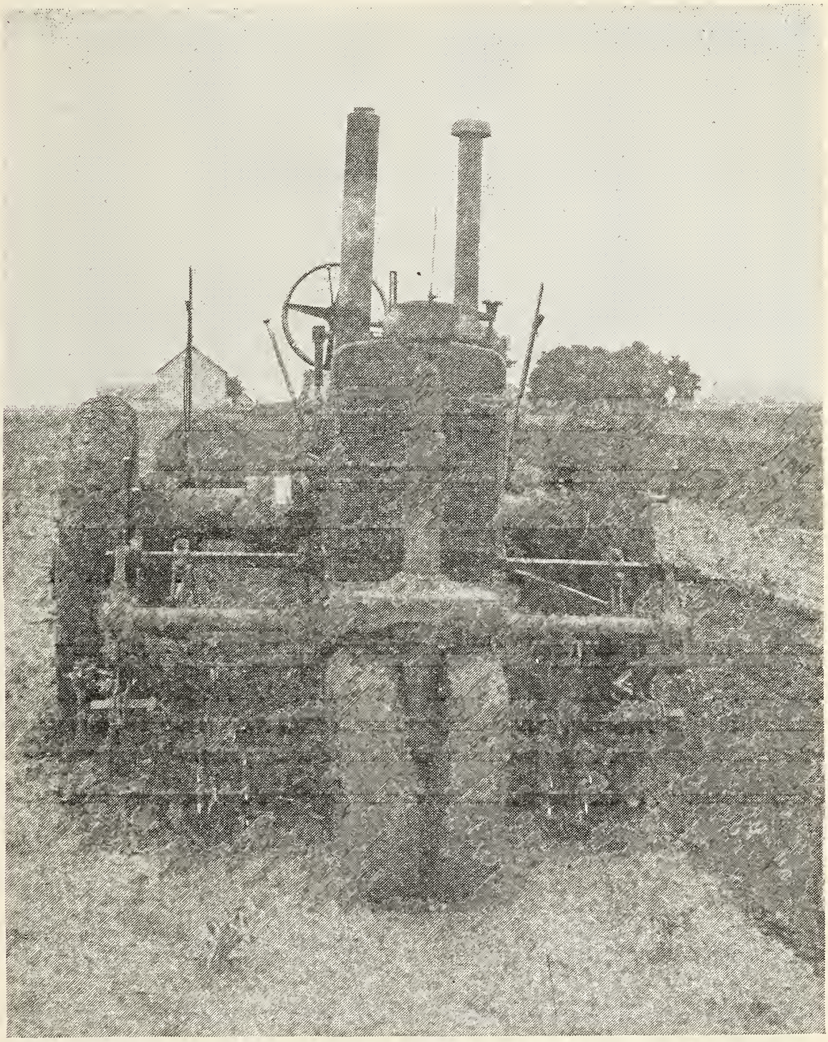

FIGURE 9.—Cultivator in the field using the same equipment as shown in figure 8.

Observations made in other experiments during this period showed that it was usually desirable to delay the first cultivation until the corn plants had grown six to eight leaves. At this stage of growth a sweep cultivator can be used without shields and enough soil can be moved

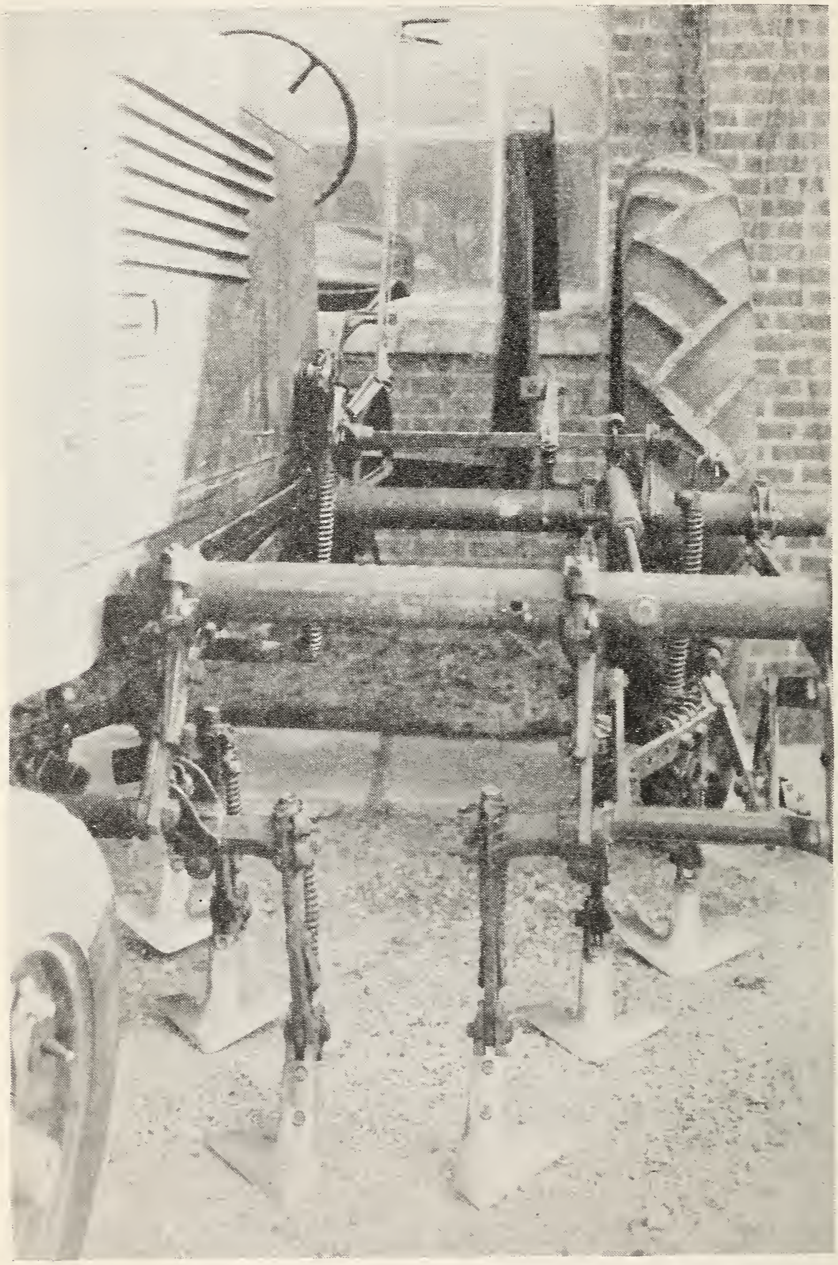

FIGURE 10.—If first cultivation can be delayed until the corn plants have grown six to eight leaves, shields are not needed. For use without shields, half sweeps are preferred rather than full sweeps next to the corn row.

into the row to thoroughly cover ordinary weed growth. For this purpose half sweeps next to the rows as shown in figure 10 have been found preferable to the full sweeps shown in figure 8.

Sweeps are generally preferable to shovels. Sweeps do not lift the soil so high and therefore have less tendency to cover the corn plants, still they can be adjusted to move plenty of soil for covering ordinary weed growth at the first cultivation. Sweep tracks overlap so that all weeds in the spaces between corn rows are sheared off without deep cultivation. Sweeps ridge the rows less than pointed shovels and are less likely to be clogged with old cornstalks or other trash.

For later cultivation the disk and sweep equipment shown in figures 11 and 12 has been found advantageous, especially in killing morning glories as well as all common weeds. Disks do not clog readily with vines or trash. Leaf guards as shown on the front disks in figure 12 are desirable if this combination is to be used when the corn plants are less than about 8 or 10 inches high. The position of the scrapers on the rear disks should be adjustable for different heights of corn. Disks with scrapers can be used when the corn is only 6 to 8 inches high as shown in figure 12. For the final cultivation, a combination consisting of a single pair of disks throwing soil into the row followed by two pairs of sweeps as shown in figure

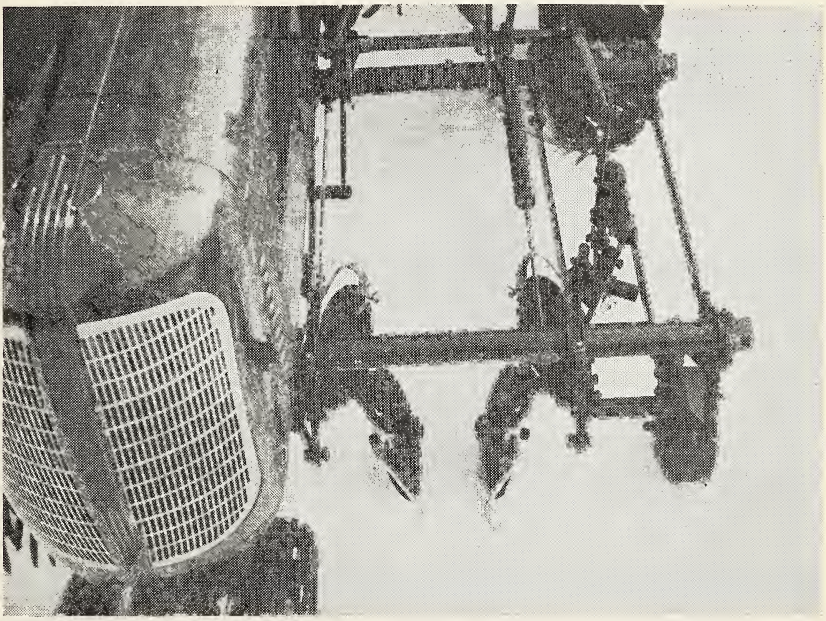

FIGURE 11.—The cultivator equipment shown here was very effective in destroying weeds. The front pair of disk hillers cut close to the corn row, throw the soil away from the row. Experimental leaf guards prevent injury of corn plants. A second pair of disk hillers throws soil into the corn row to cover weeds. Scrapers on these disks turn the soil into the row before it is lifted high enough to cover corn plants. Sweeps behind the disks cultivate the remaining space between rows.

13 is generally preferred. If scrapers are used on the disks this combination can be used also for the second cultivation.

The equipment described above may not be well adapted to all cultivators as disks and sweeps do not penetrate hard soil as readily as pointed shovels do. The cultivator should place enough weight or pressure on the sweeps and disks to force them in to the proper depth under all conditions. Disks cause side thrusts which require extra strength in the beams.

The most effective rear attachment tried for a tractor cultivator is shown in figures 14 and 15. It consists of weeder teeth set in lines diagonal to the corn rows. Set in this position, the weeder teeth move loose soil away from the corn rows, filling up tractor wheel tracks and leveling the soil between the rows, thus preventing undesirable ridging of the rows. The action of the weeder teeth in dragging weeds to the surface is effective in killing any weeds that may have been merely transplanted by the sweeps.

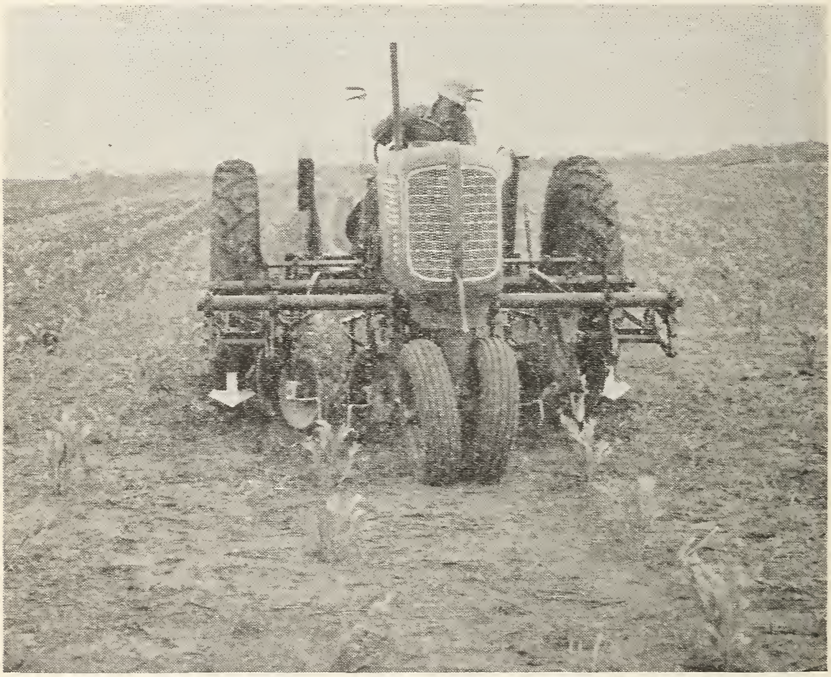

FIGURE 12.—Cultivator in the field with the same equipment shown in figure 11. This equipment was effective in killing all weeds but was especially advantageous where there were vine weeds.

The leaf guards and scrapers for disk hillers and the weeder-tooth rear attachment for tractor cultivator described above were built experimentally at Ames and, as far as we know, there is no similar equipment offered for sale by any manufacturer at the present time.

CULTIVATION OF DRILL-PLANTED CORN

In the central part of the Corn Belt, corn is usually planted in checkrows so that it can be cross-cultivated. Drill planting has been practiced to a limited extent in the past. Recently there has been a good deal of interest in contour farming for purposes of conserving soil and water. When adopting the practice of contour planting of corn, it is necessary to discard checkrowing since the checkrows must be straight while contour rows are curved. In addition to its adaptability to contour culture, drill planting saves time in planting and cultivating operations. Disadvantages are that farmers often have some difficulty in controlling weeds in drill-planted corn and there is some objection to ridging rows which may result from all cultivations being in the direction of planting.

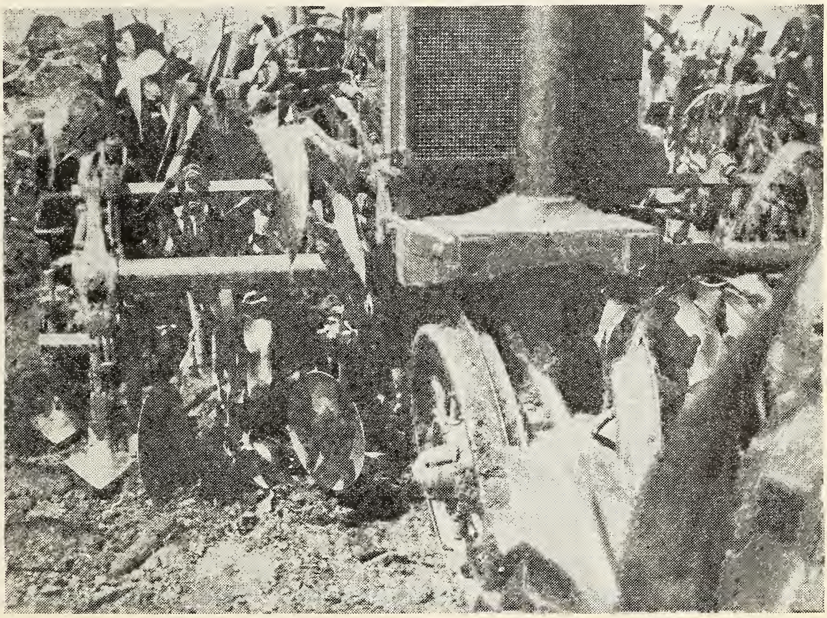

FIGURE 13.—One pair of disk hillers and two pairs of sweeps per row was good equipment for the last cultivation.

Cultivation of drill-planted corn has been studied for the past several years in the machinery experiments at Ames. It has been found that the objection to drill planting can be largely overcome by the use of the best-adapted cultivator equipment and by minor changes in standard equipment and methods of cultivation.

Special attention must be given to killing weeds in a narrow strip of soil on the corn row since this strip cannot be thoroughly tilled in drill-planted corn. The methods available for killing weeds in the corn row are: First, tillage with weeder or similar acting machine when the weeds are at the seedling stage of growth; and second, covering the weeds with soil thrown into the row by a cultivator. If a thorough kill of weeds can be accomplished at each cultivation the number of cultivations may be reduced. This avoids undesirable ridging of rows and also contributes to economy.

The amount of cultivation required is somewhat less for late-planted than for early-planted corn. It also varies with different soil and weather conditions and with different kinds of weeds to be destroyed. Based on 8 years' study at Ames, two cultivating programs for drill-planted corn are suggested as listed in table 7 which lists the stage of growth of corn at each cultivation, machines to be used and labor and power requirements. Both of these programs have proven satisfactory in experiments under normal weather conditions. Some changes may be necessary under different soil or weather conditions. These programs require a well-prepared seedbed free from growing weeds at the time of planting the corn. Program A is based upon use of a

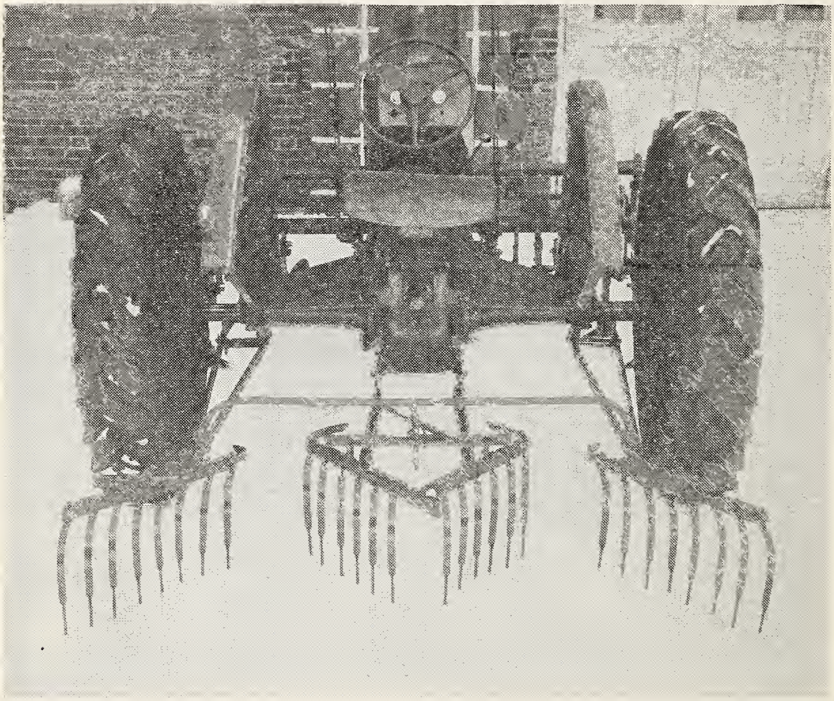

FIGURE 14.—An experimental spring-tooth weeder rear attachment for a tractor cultivator was effective in leveling the space between rows and filling tractor wheel tracks. It also improved the kill of weeds by raking them to the surface.

cultivator alone without the use of any kind of a harrow in early cultivation, while program B is based upon use of a weeder or similar machine for early cultivation.

Program A might be preferred for contour cultivation when cultivator furrows and ridges made in early cultivation would assist in reducing run-off and erosion. Program B would be preferred by some farmers when soil and weather conditions are favorable for use of the weeder. For special weed problems or wet weather, it may be desirable to add one cultivation to each of these programs; or under dry conditions on land relatively free from weeds one less cultivation than shown in table 7 may be sufficient. Earlier cultivation may be necessary under some conditions to control sand blowing. A general rule to be applied to any cultivation is that it should be performed as soon as but not before it is considered necessary for the purpose of controlling weeds or for other definite purposes.

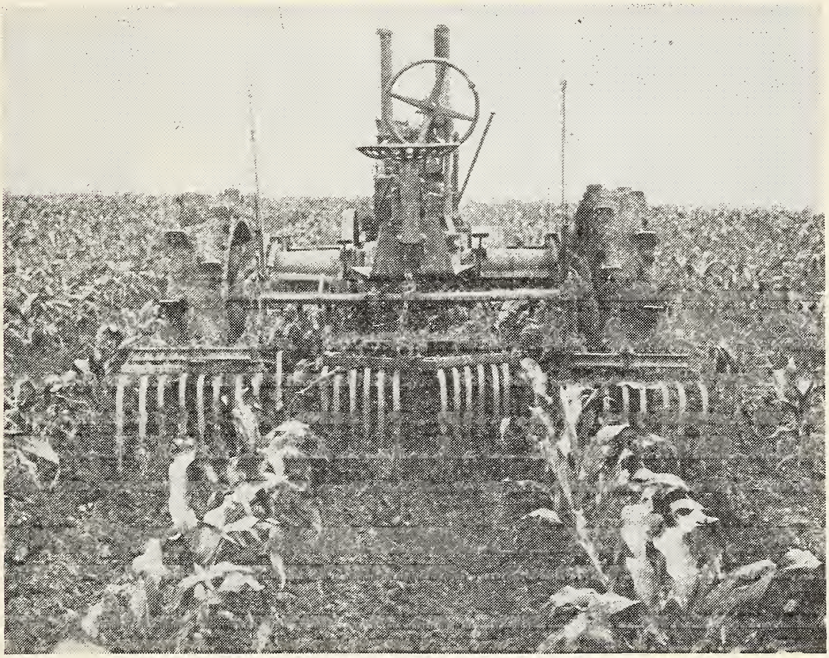

Figure 15.—A cultivator in the field with a spring-tooth weeder rear attachment similar to that shown in figure 14. This attachment is especially advantageous for cultivating drill-planted corn as it reduces the amount of ridging.

The weeder-tooth rear attachment for a tractor cultivator shown in figures 14 and 15 is especially advantageous for drill-planted corn as it reduces the amount of ridging.

TABLE 7.—*Labor and power required by two suggested cultivating programs for drill-planted corn*

Program and stage of growth of corn plants	Cultivating machine and equipment	Labor per acre	Power per acre
		Man-hours	*Horsepower-hours*
Program A:			
4 to 6 leaves	Two-row cultivator with sweeps with or without rotary hoe shields (figs. 8 and 9 or fig. 10).	0.44	2.6
10 to 12 leaves	Two-row cultivator with 2 pairs of disk hillers and 1 pair of sweeps per row (figs. 11 and 12).	.34	2.6
24 to 30 inches high.	Two-row cultivator with 1 pair of disk hillers and 2 pairs of sweeps per row (fig. 13).	.34	2.6
	Total	1.12	7.8
Program B:			
4 leaves	21-foot weeder (fig. 6)	.11	.6
8 leaves	do	.11	.6
10 to 12 leaves	Two-row cultivator with 2 pairs of disk hillers and 1 pair of sweeps per row (figs. 11 and 12 or with sweeps as shown in fig. 10).	.34	2.6
24 to 30 inches high.	Two-row cultivator with 1 pair of disk hillers and 2 pairs of sweeps per row (fig. 13).	.34	2.6
	Total	.90	6.4

CULTIVATION OF CHECKROWED CORN

The same equipment and methods described above are applicable to checkrowed corn. It is not quite so important, although it is still highly desirable, to destroy all weeds in the row at each cultivation. Cross-cultivation reduces the ridging of rows and makes it easier to get weeds under control in case wet weather has prevented timely early cultivation.

Unless checkrowing is unusually accurate, the speed of travel in cross-cultivating with a tractor cultivator has to be somewhat slower than is permissible for second cultivation of drill-planted corn. In large rectangular fields the saving of time in planting and cultivating operations by drill planting is hardly enough to justify a change from checkrow to drill planting.

LISTER-PLANTER METHOD OF CORN CULTURE

From the Missouri River west, corn planting is generally done with the lister-planter. This machine opens furrows 40 to 42 inches apart and plants a row of seed in the bottom of each furrow. The furrows are filled again by cultivating operations. This method has been studied at Ames, although it is not considered well adapted to central Iowa soils and climate.

Typical programs of field operations in corn culture by the lister-planter method are shown in table 8, which records the machines used, time of use, and labor and power in-put. By comparing these with programs recorded in table 1 for surface planting, it will be seen that labor and power expenditures in growing the crop are considerably lower with the lister-planter method.

Difficulties found with the lister-planter method at Ames were as follows: Heavy soil, especially on the lower ground, was often so wet and sticky in the bottom of the furrow at the time of planting that a good seed-bed could not be prepared in the bottom of the furrow in one operation. The lister-planter method usually produced poorer stands and lower yields than the surface-planter method especially on low ground. Yields were sometimes as much as 50 percent lower.

Experiments at various stations west of the Missouri River have shown that higher yields of corn were produced by the lister-planter than by the surface-planter method. The saving in labor and power expenditures by the lister-planter method is important under dry conditions because, when low yields are the rule it is especially important to keep operating costs at a minimum.

Table 8.—*Labor and power used in field operations in corn culture by lister-planter method with horses and tractor*

[Previous crop, corn]

HORSES FOR POWER[1]

Approximate dates	Machines used	Labor per acre	Power per acre
		Man-hours	*Horsepower-hours*
Mar. 25	Spike-tooth harrow to break stalks 20-foot, 4-horses	0.25	0.98
Apr. 5	Single-disk harrow 10-foot, 6 horses	.43	2.52
May 5	Do	.43	2.52
May 10	Lister-planter, 2-row, 6 horses	.95	5.51
June 1	Listed corn cultivator, 2-row, 4 horses	.69	2.76
June 15	Do	.69	2.76
July 2	Cultivator, 2-row, 4 horses	.59	2.33
	Total	4.03	19.18
	17–25 HORSEPOWER TRACTOR		
Mar. 25	Spike-tooth harrow to break stalks, 30-foot	0.08	0.6
Apr. 5	Single disk harrow, 14-foot	.22	2.0
May 5	Do	.22	2.0
May 10	Lister-planter, 2-row	.55	4.4
June 1	Listed corn cultivator, 2-row	.44	2.6
June 15	Do	.44	2.6
July 2	Cultivator (sweeps and disk hillers), 2-row	.34	2.6
	Total time in field	2.29	16.8
	Estimated labor servicing equipment, etc. 10 percent	.23	
	Total	2.52	16.8

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[1] Labor and power expenditures given in this table for work with horses are compiled from Iowa Agricultural Experiment Station, Bulletin No. 264, Horses, Tractors and Farm Equipment, by John A. Hopkins, Jr.

POWER REQUIREMENTS OF MACHINES

Results of draft tests of various machines available for use in corn culture are recorded in table 9. These tests were made with machines in good adjustment, operating on practically level ground. Soil conditions in each test are indicated in the table. The draft of any tillage machine—that is the pounds pull required to move it—varies according to the depth of penetration in the soil, rate of travel, previous crop and soil tilth, and kind and moisture content of soil; therefore the draft under different conditions might be more or less than recorded in table 9. Results in table 9 are shown in total draft, draft per foot of width of cut of the machine, and the energy consumed expressed in horepower-hours per acre. This last figure is a good measure of the power cost of tillage with the different machines. It is computed from the draft and width of cut of the machine.

The draft data in table 9 may be useful in selecting the right size of machines to fit different tractors. The draft per foot of width may be used for this purpose or in some cases it may be desired to find the horsepower required to pull a machine at a certain speed. This may be computed by the following formula:

$$\text{Horsepower}=\frac{\text{Total draft (pounds)}\times\text{speed (miles per hour)}}{375}$$

To use tractor power economically, a machine of such width should be selected as will make a full load, as nearly as practicable, for the tractor, allowing sufficient reserve for hills and for difficult soil conditions. When operating a light-draft machine that does not make a full load for the tractor, it is often possible to save fuel by operating the tractor in high gear with the engine throttled down to give a speed at which the machine will do good work.

TABLE 9.—*Draft of tillage machines under various soil conditions*

Machine	Depth of penetration	Soil conditions	Draft		Horsepower-hours per acre
			Total	Per foot of width cut	
	Inches		*Pounds*	*Pounds*	*Horsepower-hours*
Plow, 2-16 inch, slat moldboard 18-inch colters, independent jointers, plus 42-inch rotary hoe.	6.5	Heavy Webster soil, good condition. Oats stubble and 1-year sweetclover.	2,286	875	19.2
	6.7	Webster soil, good condition. Oats stubble and 1-year sweetclover.	2,078	807	17.8
	7.5	do	2,182	790	17.4
	5.8	do	1,551	570	12.5
	4.5	do	1,489	540	11.9
	6.1	Clarion loam soil, good condition. Soybean stubble.	1,275	506	11.1
Plow, 2-16 inch, slat moldboard 18-inch colters, independent jointers.	5.9	Webster soil, excellent condition. Oats stubble.	1,570	566	12.4
	5.5	Webster soil, dry, 2-year sweetclover.	1,563	574	12.6
Plow same as above except jointers removed.	5.5	do	1,440	532	11.7
6-foot cover crop disk (tandem disk, 22-inch blades spaced 9 inches). 320 pounds weight added. Full angle.	3.5	Webster soil, good condition. Oats stubble burnt off, poor stand of 1-year sweetclover.	1,352	225	5.0
Same except 480 pounds weight added.	3.0	Same, except stubble not burnt off and good stand 1-year sweetclover.	1,648	274	6.0
4-foot deep tillage cultivator or "chisel." Three 2½-inch points spaced 16 inches.	7.0	Clarion loam soil, good condition. Oats stubble and 1-year sweetclover.	2,413	602	13.2
	7.5	Webster soil, good condition. Oats stubble and 1-year sweetclover.	2,111	528	11.6
	8.8	do	2,598	633	13.9
21-foot single-disk harrow. 16-inch blades spaced 6 inches.	(1)	Plowed, settled, moist	2,200	105	2.3
	(2)	do	1,650	79	1.7
7-foot single-disk harrow. 16-inch blades spaced 6 inches. 320 pounds weight added.	[1] 3	Clarion loam soil, good condition. Soybean stubble.	886	127	2.8
8-foot tandem-disk harrow (cut 9 feet). 16-inch blades spaced 6 inches. 320 pounds weight added to front section.	[1] 3	do	1,422	158	3.5

See footnotes at end of table.

TABLE 9.—*Draft of tillage machines under various soil conditions*—Continued

Machine	Depth of penetration	Soil conditions	Draft		Horsepower-hours per acre
			Total	Per foot of width cut	
	Inches		*Pounds*	*Pounds*	*Horsepower-hours*
8-foot tandem-disk harrow (cut 9 feet). 16-inch blades spaced 6 inches, plus 10-foot spike-tooth harrow.	[1] 3.5	Webster soil, spring plowed, dry surface. Previous crop, corn.	1,441	160	3.5
Same, but without spike-tooth harrow.	[1] 3.5	do	1,122	125	2.8
8-foot tandem-disk harrow (cut 9 feet). 16-inch blades 6 inches, plus 10-foot spike-tooth harrow.	2.5	Webster soil, fall plowed, dry surface. Previous crop, oats, sweet clover.	1,130	126	2.8
Same, but without spike-tooth harrow.	2.5	do	813	90	2.9
11½-foot field cultivator. 8-inch sweeps.	(1)	Webster soil, plowed, moist	1,850	161	3.5
	(2)	do	1,050	91	2.0
	3.5	Webster soil, fall-plowed, dry surface.	1,620	141	3.1
15-foot spike-tooth harrow	(1)	Webster soil, plowed, moist	1,200	80	1.8
	(2)	do	700	47	1.0
	(1)	Webster soil, good seedbed	600	40	.9
	(2)	do	470	31	.7
21-foot rotary hoe	(1)	Webster soil, plowed, moist	1,325	63	1.4
	(2)	Webster soil, good seedbed	725	35	.8
3½-foot rotary hoe (as used with plow).	(3)	Webster soil, plowed, moist	102	29	.6
21-foot spring-tooth weeder	(3)	Webster soil, good seedbed	650	31	.7
2-row 14-inch lister-planter	4	Heavy Webster soil, compact, moist.	1,430	204	4.5
2-row 14-inch basin lister-planter	4.8	Webster soil, moist, soybean stubble.	1,342	192	4.2
4-row surface planter	3	Webster soil, good seedbed	425	30	.7

[1] Deep. [2] Shallow. [3] Medium.

SUMMARY AND CONCLUSIONS

SEEDBED PREPARATION

Cornstalks were covered satisfactorily in plowing under some conditions without any preparation previous to plowing.

Plowing was the only method of primary preparation of seedbed that was generally satisfactory although cheaper methods of preparation were successful under some conditions.

Better work was done by 16-inch than by 14-inch plows.

Plow jointers improved coverage of crop residues and trash.

Labor and power expenditures in plowing were about in proportion to depth of plowing.

For secondary operations in preparing a seedbed for corn, that is work after plowing up to the time of planting, it was found that:

In the absence of quackgrass or other perennial weeds, the work done by a single-disk harrow produced equally as good results as work done by a field cultivator.

A tandem-disk harrow was more effective than the single-disk harrow in filling up tractor wheel tracks and leveling off other irregularities in the soil surface. One tillage of plowed ground with tandem-disk harrow and spike-tooth harrow just before planting generally was sufficient preparation of seedbed; additional tillage did not improve weed control, stand, or yield of corn.

One tillage with a single-disk harrow or with a field cultivator proved to be insufficient preparation of seedbed in one experiment.

For lighter operations and final preparation of seedbed, the spike-tooth harrow was preferable to other machines except that a rotary hoe section was better adapted for use attached to the plow for spring plowing.

PLANTING

Comparing checkrow and drill planting, the rate of work with four-row tractor-planter was 4.5 acres per hour when checkrowing or 7.5 acres per hour when drilling.

Surface planting was generally found preferable to furrow planting, although there was no difference in yield.

Row spacings of 42 inches, 30 inches, and 21 inches, all were found to be mechanically feasible.

CULTIVATION

Early cultivation with spike-tooth harrow, spring-tooth weeder or rotary hoe was effective in killing small weed seedlings when the soil had been lightly crusted by moderate rainfall. Labor and power requirements in using these machines was low.

Early cultivation with a sweep cultivator after the corn had grown large enough for thorough coverage of weeds in the corn row destroyed practically all weeds.

In an experiment carried for 6 years, early cultivation was omitted without causing any yield reduction except in 1 year when wet weather prevented later cultivation at the proper time.

Cultivator performance was improved by use of sweeps rather than shovels. Disk hillers were the most effective equipment for covering weeds in the corn row.

An experimental spring-tooth weeder rear attachment for a tractor cultivator was effective in finishing the kill of weeds and leveling the soil between corn rows.

By use of sweeps and disk hillers and the spring-tooth weeder rear attachment, good control of weeds in drill-planted corn was accomplished without any excessive ridging of rows.

LISTER-PLANTER METHOD

Labor and power expenditures were lower with the lister-planter method of culture but yields were not so good as with the surface-planter method under central Iowa conditions.

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U. S. GOVERNMENT PRINTING OFFICE: 1940

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